Geophysical Research Abstracts
Vol. 20, EGU2018-3124, 2018
EGU General Assembly 2018

Efficient modelling of the gravity-wave interaction with unbalanced resolved flows: Pseudo-momentum-flux convergence vs direct approach

Junhong Wei, Ulrich Achatz, and Gergely Bölöni

Goethe University of Frankfurt, Campus Riedberg, Institute for Atmospheric and Environmental Sciences, Frankfurt, Germany (jwei@iau.uni-frankfurt.de)

This presentation compares two different approaches for the efficient modelling of sub-grid-scale inertia-gravity waves in a rotating compressible atmosphere. The first approach, denoted as WKB-Balance scheme, exploits the fact that a large-scale flow satisfying the geostrophic and hydrostatic balance responds to gravity waves as if it were only forced in the momentum equation, by pseudo-momentum-flux convergences (Andrews and McIntyre 1976). Present-day gravity-wave parameterizations follow this route, exclusively applying a corresponding forcing, and leaving out elastic and thermal effects. In the second approach, called WKB-Direct scheme, the large-scale flow is forced both in the momentum equation, by anelastic momentum-flux convergence, and in the entropy equation, via entropy-flux convergence. In addition, also an elastic term is taken into account in the momentum equation, as given by Grimshaw (1975) and Achatz et al. (2017). The second approach does not rely on any balance assumption with regard to the large-scale flow. We test both schemes by implementing them as prognostic WKB models, formulated in a numerically stable Lagrangian manner (Muraschko et al 2015; Bölöni et al 2016), into a coarse-resolution pseudo-incompressible flow solver, and by validating them against wave-resolving simulations. All cases considered describe gravity-wave packets propagating through an ambient flow, responding to it and also modifying it.

A budget analysis for one-dimensional wave packets suggests that the comparison between the above-mentioned two schemes should be sensitive to the following two parameters: 1) the aspect ratio between horizontal and vertical wavenumber, and 2) the wave packet scale. The smaller the aspect ratio is, the greater their differences are. More importantly, with the high-resolution wave-resolving simulations as a reference, this study shows conclusive evidence that the WKB-Direct scheme is more reliable than the WKB-Balance scheme, regardless whether one-dimensional wave packets are considered, two-dimensional cases, or two-dimensional wave packets with three-dimensional wavenumber vectors. In addition, sensitivity experiments are performed to further investigate the relative importance of each term in the WKB-Direct scheme, as well as the wave-mean-flow interactions during the wave propagation.

Reference:

Achatz, U., B. Ribstein, F. Senf, and R. Klein, 2017: The interaction between synoptic-scale balanced flow and a finite-amplitude mesoscale wave field throughout all atmospheric layers: weak and moderately strong stratification. Q. J. R. Meteorol. Soc., 143, 342–361.

Andrews, D. G., and M. E. McIntyre, 1976: Planetary waves in horizontal and vertical shear: The generalized Eliassen–Palm relation and the mean zonal acceleration. J. Atmos. Sci. 33: 2031–2048.

Bölöni, G., B. Ribstein, J. Muraschko, C. Sgoff, J. Wei, and U. Achatz, 2016: The interaction between atmospheric gravity waves and large-scale flows: an efficient description beyond the non-acceleration paradigm. J. Atmos. Sci., 73, 4833–4852.

Grimshaw, R., 1975: Nonlinear internal gravity waves in a rotating fluid. J. Fluid Mech. 71, 497–512.

Muraschko, J., M. Fruman, U. Achatz, S. Hickel, and Y. Toledo, 2015: On the application of WKB theory for the simulation of the weakly nonlinear dynamics of gravity waves. Quart. J. R. Met. Soc., 141, 676–697.